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Book reviews

LEVEL SET METHODS AND FAST MARCHING METHODS: EVOLVING INTERFACES IN COMPUTATIONAL GEOMETRY, FLUID MECHANICS, COMPUTER VISION, AND MATERIALS SCIENCE, by J.A. Sethian, Cambridge University Press, Cambridge, UK, 2nd edn. 1999 (first published 1996 as *Level Set Methods*) xviii + 420 pp., ISBN (paperback) 0-521-64557-3, (hardback) 0-521-64204-3 (Pbk, £18.95)

The two rather enigmatic terms appearing in the main title refer to computational techniques for modelling phenomena at interfaces, such as waves on water. The author of this work is ideally qualified to deal with the topic, since level set methods were introduced in a paper in 1988 of which he was a joint author, and fast marching methods were his innovation in 1996. In the book he develops the topic from first principles, and (said, I must admit, without having followed it through) his expository style is admirable. The development of theory is interspersed with helpful comments about the wider significance, and with references to publications dealing with the latest developments.

Of the two techniques, it appears that fast marching methods often allow, as might be expected, solutions that are less time-consuming, but they do not entirely supersede level set methods which have wider applicability. It is acknowledged that there are other methods besides these that can be considered for problems of the kind, and while the author is careful not to be dogmatic about the superiority of this favoured techniques, he makes it pretty clear that one of them will almost always be the method of choice. Older methods operate by placing a series of markers along the evolving boundary (if in two dimensions) or over the boundary surface (in three dimensions), and then letting these markers advance as the simulation runs.

The trouble with such methods is summed up in the author's website (see below) as follows: "Such schemes usually go unstable and blow up as the curvature builds around a cusp, since small errors in the position produce large errors in the determination of the curvature." The methods described in this book use a quite different approach that avoids the difficulty and leads to robust and accurate and efficient operation. The methods handle problems in which the separating interfaces develop sharp corners an cusps, and become truly intricate. They are even applicable to situations in which the physical events on each side of the interface both drive its variations and are affected by its location and properties. Such situations include combustion and flame propagation, crystal growth and dendritic solidification, among others.

Impressive though all this is (and one of the attractive features of the author's style is his infectious enthusiasm) there is much more to come since the techniques find important applications in apparently-unrelated fields. One of these, likely to be useful in a wide range of robotic schemes and as a part of other kinds of numerical simulation, is to the forming of rectangular grids of points around complex body shapes. Associated with this is the means of drawing geodesics, or shortest paths, on arbitrary three dimensional surfaces.

The methods also find application in a remarkable number of areas related to image processing, including the extraction of 3-D shape from shading, and the extraction of images from noise. These have been applied in medical imaging. The cleaning-up of noisy images is illustrated in its application to character recognition, where the new methods allow noise reduction with much less loss of definition than in older methods operating on neighbourhoods of pixels. Essentially, the picture is treated as a 3-D shape with height corresponding to intensity, and then the shape is made to evolve like a fluid with surface tension, whereupon the images of characters usefully coalesce.

The relevance to character recognition is not restricted to this cleaning-up process. Another application is demonstrated, in the classical task of recognition of sloppy hand-blocked characters. The new techniques can be used as an adjunct to a recognition scheme, so that when submitted images are rejected as unrecognisable, the techniques allow modification of the image in ways that often let it be correctly classified when resubmitted.

An application to aircraft navigation is also described, having a bearing on the optimal course for an aircraft finding itself uncomfortably close to another, given that the action that will be taken by the other craft is not known with certainty.

Apart from these wide-ranging areas of application, the methods have also proved their worth in what may be considered more their home ground, namely in the development of micro-electronic components. The various processes of deposition and etching are all subject to uncertainty as to just what is etched or exactly where deposits form. At least, that has been so in the past, so that development has involved numerous trials of physical component construction. The new computing methods now allow the processes to be modelled in computer simulations, and the last chapter of the book treats this valuable area of appication.

The author very generously gives his *e*-mail address and invites correspondence. He also gives the address of his website, as: <http://math.berkeley.edu/~sethian/level_set.html>. The website is a magnificent piece of work, and quite delightfully presented. For example, the user is invited to download pieces of movie animation that illustrate aspects of the theory. The movies can be made to run through from start to finish, or can be taken back or forward to any point in their run-time by a slider that can be dragged by the mouse pointer. There are also "Java applets" that run as interactive programs and that for example allow the user to set up an arbitrary shape to be operated on by the simulation method, or to create his own images to be cleaned-up of noise.

The website contains both a movie and an applet that illustrate robotic path planning through a maze. This is also treated in the book, as part of the general topic of shortest paths. The website also gives a reference, and abstract, to a popular account of the topics in the *American Scientist* for May–June 1997 Volume 85, No. 3, as well as many other references, some of them to papers that can be downloaded in full. Both website and book can be thoroughly recommended.

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METHODOLOGY AND TOOLS IN KNOWLEDGE-BASED SYSTEMS: LECTURE NOTES IN ARTIFICIAL INTELLIGENCE 1415, SUBSERIES OF LECTURE NOTES IN COMPUTER SCIENCE, edited by Jose Mira, Angel Pasquel del Pobil and Moonis Ali,. Vol. 1, (Springer, Berlin, 1998) xxiv + 887 pp.

Researchers in robotics and automation need to know about the progress that is being made in Artificial Intelligence and in particular, about knowledge-based systems. This text and its companion volume provide an opportunity to keep up-to-date in the field.

The 11th International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems IEA-98-AIE, held at Benicàssium, Castellón, Spain, June 1–4, 1998, has been given extensive coverage by the publishers Springer, and the proceedings have been published in two volumes of some 2000 pages. Volume I has the title *Methodology and Tools in Knowledge-based Systems and Volume II: Tasks and Methods in Applied Artificial Intelligence*.

The temptation is to review the two together but the division into the two has to be respected even if the editors were content to reprint the same preface in each volume. Volume I is considered here but both are contributions to the conference's "theme for 1998" which was *New Methodologies*, *Knowledge Modeling and Hybrid Techniques*.

In their preface the three editors of Volume I reiterate what is the accepted aim of Applied Artificial Intelligence, that is to 'render computational a large portion of non-analytical human knowledge'. This they say is done by first building knowledge-level models of analysis and synthesis tasks in scientific and technical domains, such as those performed daily by human experts in the field. There are numerous examples of these fields and more are appearing in rapid succession. They range from Medical Diagnosis, Telecommunications Engineering, Architecture to Education. What is then required is that these models of such widely differing applications are transformed so that their entities and relations can be linked to the primitives of a programming language. Finally, we are told by the authors, a computer program can be produced which is then subject to the usual software engineering 'checks and balances'. They write about validation, evaluation and maintenance at a time when the worries of the arrival of the year 2000 demand that the word verification should be a dominant feature of any software engineering program.

The organisers of this conference have recognised that there has been concern about the sound foundations and methodology, as well as the necessity of developing efficient procedures to make models operational. Most researchers and developers in this area would agree that since its origins in the 1950s there has been a lack of methodology and foundations, and would welcome any attempt to make Knowledge-Engineering into a more robust discipline, and study. The papers published in this Volume attempt to do that, and we are told they have been conscientiously reviewed by two referees per paper. The papers published are said to be the final version of the accepted papers that incorporate the reviewers' comments. Readers, however, are entitled to ask whether they contain the views of other participating delegates. The current formula of organising conferences seems to preclude any opportunities for authors to revise their papers as a result of their presentations and the resulting discussions. Unfortunately, nowadays we are, on arrival at a conference, given a published version of all accepted papers. In this Volume the published contributions have been limited to some 10 pages per paper. It is therefore not clear whether these were the versions published before the meeeting and consequently were, perhaps abridged versions, or very short presentations. Readers may well agree with the publishers and the conference organisers that two volumes of proceedings is enough and being succinct has advantages not only for conference goers but also for referees and in particular, book reviewers.

As to the standard and variety of the papers included in this collection of contributions the editors tell us that of the 291 contributed and invited papers submitted from 41 countries 187 were selected. The range of topics must have been encouraging to workers in this *AI* research area. To help readers the volume is divided into four main parts: Methodological Aspects (7 papers), Knowledge Modelling (7 papers), Formed Tools (8 papers), and Generic Tasks of Analysis (6 papers).

The divisions of topics into these sections follows the "Call for Papers", but some additional ones have been included as a result of them being the subject of invited sessions. The list included here gives a guide therefore to both the standard of the contributions and also to the popularity of certain lines of research and development. It would, of course, be interesting to know how many papers in each section were refused by the referees, a statistic that not many editors of books or journals are happy to divulge! The editors are absolutely right when they say that one of the most frequent deficiencies in the majority of methodological developments lies in ignoring the conclusive step about how to render the models operational with the final result of an implemented system. This does lead to both scepticism about some contributions and also, in general, accounts for the evident lack of credibility seen towards many of the *AI* researches. The real world often appears to be a distant place and applications relevent to it not considered seriously. The editors in their preface have summed up the situation in an honest way; they say: " *AI* researchers are sometimes seen as just blowing smoke". Potential readers of this volume should appreciate that when they peruse it, should the questions be asked such as: what support is there for this claim and why isn't a rigorous methodology applied?

That said, there is much of great interest in the text and it was often a pleasure to see the mathematical approach to so many aspects of this research meeting with success. Most contributors realise the need for precision in their research and where possible, the presentation of rigorous and validated results of real-world applications and problems are the yardstick by which their work should be measured. Discussion papers are, of course, highly desirable and a paper such as Fraňová and Kooli of the CNRS and the Université Paris Sud, on 'Theory of Constructible Domains for Robotics: Why?' is one which is both stimulating and useful. Other contributions deserve similar praise. It was surprising that only one paper on Neural Networks was included. Brasil et al., whose authors mainly did come from the Federal University of Santa Catarine in Brazil, examined both complexity and cognitive computing. They described a hybrid expert system to minimise some of the complexity problems presented in the *AI* field. Most readers will agree with the assessment of these authors that the complex systems associated with human activity are often pooly defined. They believe that cognitive computing provides an effective and efficient way to analyse technological processes and human activities.

An author Index is provided which is in itself a useful Who's Who of scientists working in the various fields.

The Lecture Notes series by Springer has provided some valuable texts, and those in the fields of Artificial Intelligence and Computer Science have enhanced this reputation. Publishing the proceedings of a conference presents innumerable problems and readers need to be aware of what they are buying. Short contributions can only whet the appetite or, indeed, discourage one from buying such a volume. This volume has been well presented and the papers properly refereed and edited. It would therefore be worthwhile volume to peruse at one's leisure and a useful reference for, at least, the immediate future. It also has an historical significance and that in itself makes it a text worth consulting in the department or institutional reference library.

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WORLD ROBOTICS 1998 – STATISTICS, MARKET ANALYSIS, CASE STUDIES AND PROFITABILITY OF ROBOT INVESTMENT, co-authored by: The International Federation of Robotics (IFR) with the United Nations Economic Commission for Europe (UN/ECE), United Nations, Geneva, Switzerland, 1998 viii + 299 pp.

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This is a very commendable joint publication co-authored by the International Federation of Robotics and the Economic Commission for Europe's Statistical Division. Readers should not be put off this publication because it is dated 1998. Although later statistics are now available texts of this nature that produce and publish yearly data and trends must necessarily be at least twelve months behind the current state. It takes at least that length of time for the accurate figures, as opposed to statistical predictions and raw results, to be compiled and analysed.

Both Tom Griffin (UN/Economic Commission for Europe's Director of the Statistical Division) and Rolf Schraft (Chairman of the International Federation of Robotics) agree that:

> "Since their introduction at the end of the 1960s industrial robots have undergone an impressive technological evolution. With declining real prices and continuously improved performance, robots are now widespread in industry in many countries, while in others the technology is on the verge of being introduced. Robotics have become a symbol of industrial automation in its most advanced form."

Few researchers and developers would disagree that the current stage is one frequently predicted by the great names in the field as one of the ultimate goals of a controlled society. This text helps us to realise these advances are actually happening and the statistics are produced to prove it. What these figures show is that robots form the centrepiece of computer intergrated manufacturing systems. They have become, the co-authors say, 'the symbol of industrial automation in its most advanced form'. What is often forgotten, and the statistics and comments in this joint publication quickly remind us about, is that introducing robots into industry is a 'double-edged' operation that is motivated not only by the need to improve productivity but also to obtain a better and more consistent product quality.

We are told, for example, that the total accumulated yearly sales of robots since the beginning of the 1970s amounted at the end of 1997 to about 950,000 units of which 710,000 are estimated to be in operational use. The published tables also indicate that there is a range of new applications that appears to be growing so that it is not only in industry that robotic systems are found, but also in construction and in the services such as hotels, health care, laboratories, surgery, etc. . . . A great potential for new applications is apparent, and there is every reason based on the information supplied in the text to believe that robotics will continue in its present upward path and play an increasingly important role.

This publication is divided into six sections and provides an Annex of Tables. The present text has been renamed from *World Industrial Robots* to *World Robotics*. This is because the compilers have recognised the roles of not only industrial robots but also service robots. The publication does, however, recognise that for many years ahead the focus will still be on industrial robots. A new section has also been added which contains case studies of actual robot installations. What is important is that this study of actual cases is designed to show the effects that robots have had on costs, production and employment structure as well as giving an indication of that essential constituent to any such study – profitability. Another innovation that readers of previous editions will notice is the addition of a special study on *Robotics in the Food and Agriculture Industry*. This benefits from an introduction written by Mike Wilson of the British Robot Association (BRA) to three interesting and useful articles on: MAFF-Fact Finding Mission on Robotics – 'Out of the factories and into fields' (BRA); Robotics in Packaging: 'The Adept Experience' (C. Duncheon, Adept Technologies Inc. USA); and 'Putting the Icing on the Cake' (I. Rennell, R. Williams and T. Simpson).

Once again the question arises as to what is an industrial robot and what is a service robot. Definitions seem to vary from publication to publication and country to country. One writer neatly defined these as any definition that provides a better set of robotic statistics for the government department charged with supplying them. The IFR has, however, adopted a preliminary definition with the *caveat* that it is subject to change based on experience gained of collecting the appropriate data. Since the whole credence of this UN/IFR statistical summary depends on such definitions, readers are advised to consider them most carefully. *A Service Robot*, for example is defined as:

> A robot which operates semi or fully autonomously to perform services useful to the wellbeing of humans and equipment, excluding manufacturing operations.

We are told that with this definition manipulating industrial robots could also be regarded as service robots provided they are installed in non-manufacturing operations. Further semantics tell us that service robots may or may not be equipped with an arm structure like an industrial robot. Service robots often, but not always, can be mobile. The different types of service robots are illustrated in the text to help the reader in categorising the current robot population.

According to the definition ISO 8373 we have the ability to recognise a manipulating industrial robot as an:

> automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.

As with all definitions, the terms used have to be defined or at least explained, and this has been done satisfactorily.

Most people rarely read a statistical publication since it is prepared after all to provide data. This book does, however, have some 'readable' text to accompany the large array of statistical tables and figures. Essentially it is, of course, a reference book and a very useful one in a series that is worth preserving if only to appreciate the time series data.

An 'executive Summary' provides an excellent précis of what is to be provided. Indeed, the Table 1 provides a fascinating insight into the distribution of installations of robots and the forecasts for 1998–2001. The countries Japan, USA, Germany, Italy, France and the U.K., the 'Big Six' as they are called, had 71,377 robot installations in 1997 and are forecast to have 99,300 in 2001. They completely outshine all the other nations listed who together can only muster 13,510 in 1997 and are predicted to have 20,500 robot installations in 2001. This level of activity and development is mirrored in other data produced by these countries.

The main *Introduction* deals with many subjects, including the problems of definition and classification of robots by type and application area. Readers are advised to read this thoroughly before using the data tables and figures that are provided in the following sections. These sections look at: Worldwide diffusion of industrial robots; structure of the diffusion by individual countries; forecasts of the investment in industrial robots (1998–2001). The final sections consider *Robotics in the Food and Agriculture Industry* and the profitability of industrial robots – with the very useful analysis of case studies. Finally, the Annex has some detailed tables which show on a yearly basis (1981–1997) the trends in such factors as yearly sales of industrial robots, stock and shipments.

There is no doubt about the importance of this publication which is claimed to be the 'World's only publication that presents comprehensive statistics on industrial as well as service robots. Its detailed statistical data for 20 countries make it an essential reference text. It also contains trends and prediction data and information about developments in 1997 with its forecasts reaching 2001.

Readers do need, however, to realise that it is based on data collected from and transmitted by more than 20 countries by their national industrial robot associations. In addition, researchers who use the text, should analyse the definitions of the robots referred to and the categories they have been placed in. With this in view, it is considered a worthwhile publication that has been carefully prepared, and access to it is surely essential to all developers, practitioners and researchers in these fields of endeavour.

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OBJECT RECOGNITION IN MAN, MONKEY, AND MACHINE, edited by Michael J. Tarr and Heinrich H. Bülthoff, MIT Press, Cambridge, Mass. (Bradford Book), 1999, 217 pp., ISBN 0-262-70070-0, (Pbk, £17.50 (Reprinted from *COGNITION: International Journal of Cognitive Science*, vol. **67**, Nos. 1–2, July 1998, published by Elsevier, Amsterdam)

The cover of this book shows a reproduction of the Warhol picture of a Campbell's soup tin, no doubt acknowledging that important questions about visual perception can be illustrated in everyday contexts. The slightly gaudy appearance of the cover disguises the fact that the book contains seven valuable papers covering the latest developments and thinking about visual object recognition. The editors are well qualified to deal with the topic, as one belongs to a relevant department in Brown University, Providence, Rhode Island and the other is Director of the Max Planck Institute for Biological Cybernetics in Tübingen, Germany.

In the first of the seven papers the two editors refer to a previous special issue of *Cognition*, in 1984, on "visual cognition", with object recognition as one of the main themes. They observe that in the intervening years there has been enormous progress in understanding, along with a certain change of viewpoint. The central problem of object recognition arises from the fact that three-dimensional objects are recognised from two-dimensional retinal inputs, where the two-dimensional views vary with orientation of the object and other factors.

In 1984 the approach was strongly influenced by the work of David Marr, who suggested a rather complete three-dimensional reconstruction, so that recognition might be said to be "object-centred". Subsequent studies have favoured a more "viewer-centred" or "image-based" approach in which recognition comes more directly from detection of local features of the two-dimensional scene. It is emphasised that the earlier view is not completely abandoned since certain observations still support it. Both types of recognition mechanism appear to be used in the brain, but a large amount of evidence indicates that the "image-based" approach plays a major part, and merits a corresponding place in recognition artefacts. The inadequacy of a strictly "object-centred" approach is confirmed by the limited success of artificial schemes based on it.

Support for the altered viewpoint comes from work under three main headings whose evidence is described as converging. These are human psychophysics, neurophysiology, and machine vision. The first of the following papers is mainly concerned with machine vision and is by Shimon Ullman on "Three-dimensional object recognition based on combination of views". It is illustrated by processing of views of a model Volkswagen Beetle car from two different angles so as to synthesise a view from an intermediate angle, and similar transformations are performed on images of faces. The relevance to human and other primate perception is discussed with the conclusion that object recognition should not be viewed as a single process and may be due to many quite different interacting processes.

The following paper is on "Recovery of 3D volume from 2-tone images of novel objects" and is primarily concerned with explaining certain aspects of human visual perception. Pictures of familiar objects, using only two tones (i.e. black and white) are readily recognisable, but this is shown to involve top-down processing depending on memory of the objects, since unfamiliar objects are much less readily ascribed three-dimensional shapes. The following paper, having the first-names editor as joint author, treat a related issue, namely the reconciling of the image-based approach with the fact that people can generalise over object classes and can recognise objects from unfamiliar viewpoints. Techniques of computer graphics are used in the experiments.

The following paper has the title "Evidence accumulation in cell populations responsive to faces: an account of generalisation of recognition without mental transformations". As indicated by the explicit reference to cells, this reports neurophysiological experiments on monkeys, with recording from single neurons. A large and complex mass of data is presented in support of the thesis, and there are many references to earlier studies by the same group. The detailed results here are a major piece of evidence supporting the new viewpoint on object recognition, and account for the reference to "monkey" in the book's title.

The remaining two papers treat particular aspects of the relationship of object recognition to other functions. In the former, it is pointed out that object recognition tends to be considered separately from categorisation, although the two must interact or even by aspects of one process. A new principle of "diagnostic recognition" is introduced.

The final paper remarks that vision not only serves object recognition but also other purposes, particularly determination of action. The latter requires not only recognition but also, at the very least, estimation of position and orientation of the object, and of rates of change. The discussion is related to brain function and to observations on brain-damaged subjects.

There is clearly a great deal of important material in this book, which brings readers up-to-date on current thinking in this important area, with implications for psychology and neuro-physiology as well as for advanced robotics.

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